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Shear Strength Analysis of Dissimilar Materials Bolted Joint

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ABSTRACT

Several studies have been carried out on joining of dissimilar materials. The beginning of composite materials in the automotive engineering creates latest demands on the materials and manufacturing sectors in terms of cost, durability and automation. Manufacture and assembly of composite structures needs more knowledge of reliable joining techniques. The most common joints are formed using Mechanical fasteners. Structural applications of composite laminates are increasing with the drive for high strength, light weight component design. These applications usually required joining composites either to composite or metals. Therefore, appropriate prediction method must be developed to conclude the failure strength & failure modes of their bolted connections. This type of joint is employed in automobile applications like door panels, bumper and also in aeronautical application. The purpose of the bolted joint is to transmit the applied load from one part of the joint structure to the other through the fastener element. Unlikely, the presence of bolt holes induces larger stress concentration which leads to be a source of damage developed during loading.

The ultimate goal of this project is to address the shear strength of the Mild Steel-Aluminum and Mild Steel-Glass fiber reinforced polyesters materials bolted joints using finite element method and experimental method. The single lap single bolted joint was designed using Creo 3.0 and simulation was carried out using Ansys workbench 17.0. The experimental analysis was carried out as per the ASTM standards. Finally, from the comparative study it shows that the Mild Steel-Glass fiber reinforced polyesters has better shear strength than the Mild Steel-aluminum materials joint. From the investigation, it shows that the finite element results as appropriately matches with experimental results with minimal error.

KEYWORDS: *Composites, Joints, Lap joint, Mild Steel, Aluminum, GFRP, Shear strength.*

1. INTRODUCTION

In the development and improvement in technology and engineering practice, the automobile, aerospace and marine industries is becoming progressively difficult to sustain due to establishment of more manufacturing companies and global contest between them where fuel efficiency and safety being more important one. So, the opportunity is brighter for industries which have safer structural design and less weight. The study in modern years has shown that composite materials are not only less weighted but also have higher strength to weight ratio. High strength provides durability and less weight improves the pay load capacity [1]. As composite material become more common in new design, many situations arise in which they are required to join along with conventional homogeneous and heterogeneous materials. Specifically, in automobile and other application joining of dissimilar materials i.e., metal to composite connection is necessary which improves the strength and reduce the weight of the material. The design of joints has emerged as a completely critical studies area since the structural efficiency is decided by the stiffness of the joints not by its basic structures [2]. In joining of dissimilar structures, there are three types such as adhesive bonding, mechanical fastening and welding These joining processes can be used individually or mutual in single method to make sure a success and life of joint between dissimilar structure [3]

Ricardo de Medeiros et, al [4] has investigated on the mechanical behavior of single lap single bolted joints for titanium and composite structure using experimental and finite element method. They have concluded that the new experimental method can help the engineers to design similar metal-composite joints and also possible to study the different design parameters such as strength, limit stress and modulus of elasticity for metal-composite joints. Geoffrey Turvey et.al [2] has investigated on failure of single lap single bolted joint in glass fiber reinforced plate. In this paper work, they have determined the ultimate load and strength of pultruded glass reinforced polymer composite under tensile load by experimental method. They have concluded that with increase width to hole diameter ratio and edge distance to hole diameter while have higher strength. They also concluded that the failure modes are depends on the design parameters i.e., W/D and E/D ratios.

The present study aims to determine the shear strength of the metal to metal and metal to composite bolted materials joint using experimental and finite element method. Finally, the results obtained from the two methods are compared.

2. Methodology

It is a logical and theoretical investigation process employed in the field of analysis or studies. It includes design, preparation, completion and achievements of the studies. Figure 1 shows the flow of the project work.

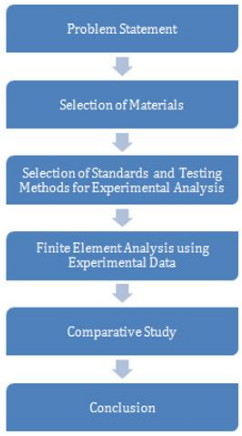

Figure 1 Flow chart of the Project work

3. Experimental Analyses

In most bolted connection, the bolts are subjected to shear and bolts can fail in shear or in tension. So it is necessary to know the strength of the joint under the shear conditions. As there are no such specific standard methods for determining the shear strength of the dissimilar materials single bolted joint, ASTM D5961 [5] provides a methodology to determine the shear strength of the composite-composite material joint. Figure 2 shows the image of test specimen used to determine the shear strength of the joint.

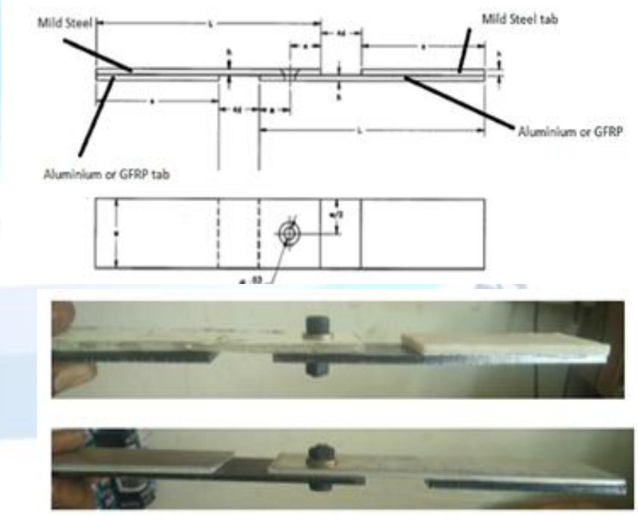

Figure 2 test specimen used to determine the shear strength of the joint.

The test was performed in the universal testing machine as per ASTM D5961 standard for both the Mild Steel-Aluminum and Mild Steel-GFRP joints for two samples each. The test has been performed till the samples break. The Figure 3 shows experimental load value at different cross head travel for MS-AL and MS-GFRP materials joint in shear test. The ultimate load of the MS-AL and MS-GFRP is 6950N and 7450N respectively.

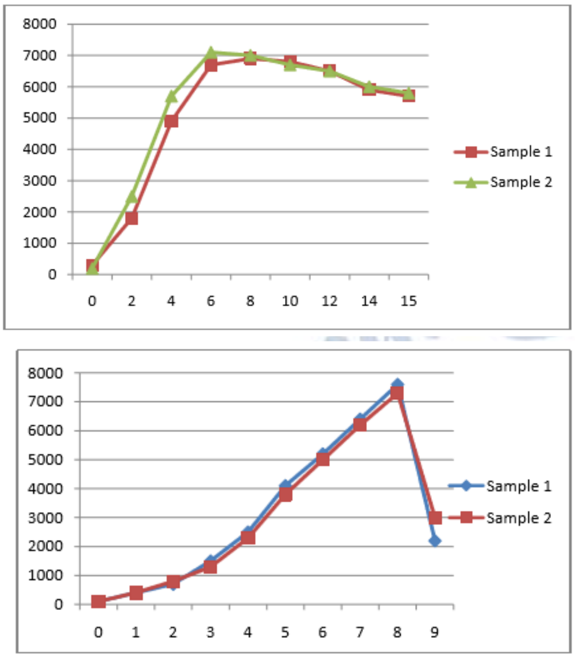

Figure 3 Load value at different cross head travel for MS-AL and MS-GFRP materials joint

The Shear Strength of the joint is determined by using the formula, S = F / A (MPa)

Where, F= Load (N), A= Area of hole (mm2) = (3.141/4) *d2 = (3.141/4) * 62 = 28.3 mm2

Ultimate shear strength of MS-AL joint, Sult= (6950/28.3) = 245.93 MPa.

And, Ultimate shear strength of MS-GFRP joint, Sult= (7450/28.3) = 263.6 MPa.

From the analysis, it shows that the shear strength of the MS-GFRP joint is better than the MS-AL joint. The Figure 4 shows the image of the failed specimen. The failure mode of MS-AL is Shear out and of MS-GFRP is net tension failure.

Figure 4 Failed Specimen of MS-AL and MS-GFRP in Shear test

4. Finite Element Analyses

The finite element analysis is carried out using average load from the experimental data and the bolted joint specimen is designed as per standards used in experimental method for different analysis. The simulation is carried using the analysis software Ansys 17.0.

In meshing, a quadrilateral type of mesh is used for both types of material joint. The number of elements and nodes obtained are 3121 and 12612 respectively. The boundary conditions are applied as per experimental condition. Here, the Mild Steel end of joint model is fixed in all the three direction and the tensile load is applied at the AL or GFRP end of the joint model, which has free displacement in x direction. The Figure 5 shows the boundary conditions for materials joints under shear.

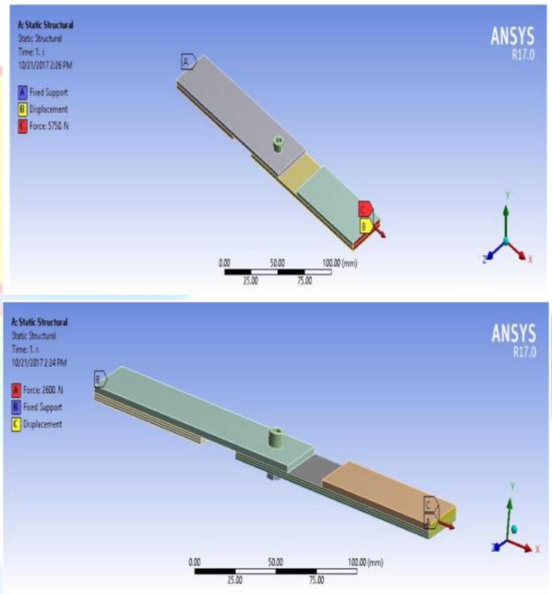

Figure 5 Boundary condition of MS-AL and MS-GFRP joint for shear

The finite element analysis has been carried out for ultimate load which is obtained from experimental verification for both types of joint. The Figure 6 shows the shear strength value for ultimate load of 6950N and 7450N for MS-AL and MS-GFRP materials joint respectively. The results obtained are 245.9 and 426.1Mpa for MS-AL and MS-GFRP materials joint respectively.

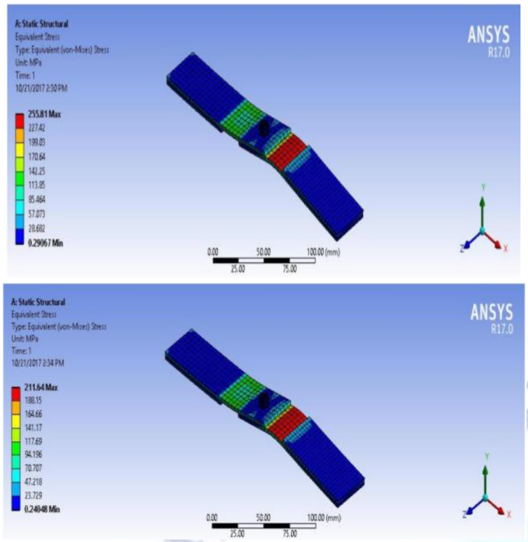

Figure 6 Shear stress of MS-AL and MS-GFRP materials joint for ultimate load

From this analysis, it shows that the Shear Strength of MS-AL joint as higher strength than the MSGFRP joint.

5. RESULT AND DISCUSSION

The ultimate shear stress obtained for different materials joint using experimental and FEA is as shown in Table 5.1. It shows that the shear strength of the joint is higher for mild Steel -GFRP material joint than the Mild Steel –Aluminum joint. The shear strength analysis of the joint has 4% and 15.4% of error between Experimental and FE analysis for MS-AL and MS-GFRP joint respectively.

Table 5.1 Shear strength of the joint using FEA

Types of materials joint	Experimental Analysis (MPa)	Finite Element Analysis (MPa)	% Error
Mild Steel – Aluminium	245.9	255.8	3.9
Mild Steel – GFRP	263.9	311.6	15.4

6. CONCLUSION

In this present work, the MS-AL and MS-GFRP materials single bolted single lap joint has been analyzed. The shear strength of the bolted joints have been analyzed using experimental and finite element method. In experimental analysis, a two set sample were prepared as per ASTM standards and carried out the shear test was carried out. The average load obtained from the test has been used in empirical formulae to determine the shear strength. In case of FE analysis, the models are generated as per ASTM standards which are used in experimental work using Creo3.0 and the simulation was carried out using Ansys package. In simulation, average load obtained from the experimental work has been applied on the model to verify the shear strength. Finally the results of joints of dissimilar materials were compared and concluded as follows:

the MS-GFRP materials single bolted joints has better strength compare to MS-AL materials single bolted joint under Shear loading

The experimental method has good agreement with Finite Element method with optimal errors.

From the above comparison, it shows that the MS-GFRP joint has better properties compare to MS-AL joint.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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